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APPENDIX A

ANALYSIS OF COOLING-HEATING-COLLECTIVE PROTECTION FOR AN/GSM-44 SYSTEM

CONTRACT: DA18-035-AMC-305(A)

DECEMBER 1964

HUGHES AIRCRAFT COMPANY

FULLERTON, CALIFORNIA

APPENDIX A

ANALYSIS
OF
COOLING - HEATING - COLLECTIVE PROTECTION
FOR
AN/GSM-44 SYSTEM

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ANALYSIS

OF

COOLING - HEATING - COLLECTIVE PROTECTION

FOR

AN/GSM-44 SYSTEM

INTRODUCTION

This analysis was performed under contract DA-18-035-AMC-305(A) upon the request of CRDL/Edgewood Arsenal representatives when it was confirmed that air conditioning equipment would not be furnished by the Government for the AN/GSM-44 System.

Purposes of the analysis are to show the internal temperature conditions which will exist in the AN/GSM-44 Shelter when Collective Protection Equipment is used with different types and capacities of CB Filter Units, and to present various possible approaches, with comments and recommendations, for adapting CPE to the AN/GSM-44 System.

DEFINITIONS

For purposes of this analysis, expressions used herein are defined as follows:

CPE - Collective Protection Equipment.

P.E. - Protective Entrance.

CB Filter Unit - A unit for removing Chemical - Biological contaminants from the make up - ventilation air stream.

AMBIENT - The atmosphere surrounding the Shelter and CB Filter Unit.

SUMMER OPERATION - Utilization of the complete AN/GSM-44 System at high ambient temperatures. (70°F to 125°F).

WINTER OPERATION - Utilization of the complete AN/GSM-44 System at low ambient temperatures. (+60°F to -65°F).

SECTION I

AN/GSM - 44 SYSTEM

SUMMER OPERATION

A. Existing Internal Conditions without Collective Protection Equipment.

B. Operating Conditions With Collective Protection Equipment.

C. Cooling Requirements With Air Conditioning and Collective Protection Equipment.

A. EXISTING INTERNAL CONDITIONS

1. At the present time there are no provisions made or planned for air conditioning the AN/GSM-44 System during summer ambient conditions. Shelter and equipment cooling are accomplished by forced ventilation created by two exhaust blowers located in the end wall of the shelter, opposite the door. Air intake to the shelter is via of an opening in the shelter door. The exhaust blowers are rated at 750 cfm each (free delivery), however it is obvious that the airflow restrictions imposed by the door inlet filter, and "blackout" type louvers and sound muffling covers over the blowers reduce the airflow to a value far below the free delivery rating. It is estimated that a total airflow of approximately 1000 cfm maximum will occur during the summer ventilation mode of operation.

2. Figures 1 and 2 are curve sheets plotted from calculated data, to illustrate the shelter internal conditions at 125° F and 100° F ambient respectively. Curve A on each figure represents the basic S-141/G shelter heat gain by means of transmission through the roof, walls, and floor. It was assumed in the calculations that the shelter is standing in the sun and subjected to solar radiation, and that the overall heat transfer coefficient of the shelter (U factor) is 0.35 BTU per(hour) (sq. ft.) (° F temperature difference).

   When internal heat loads are dissipated into the shelter, Curves B and C are obtained for the AN/CSM-44 operating under part load and full load conditions, respectively. The internal heat loads were calculated

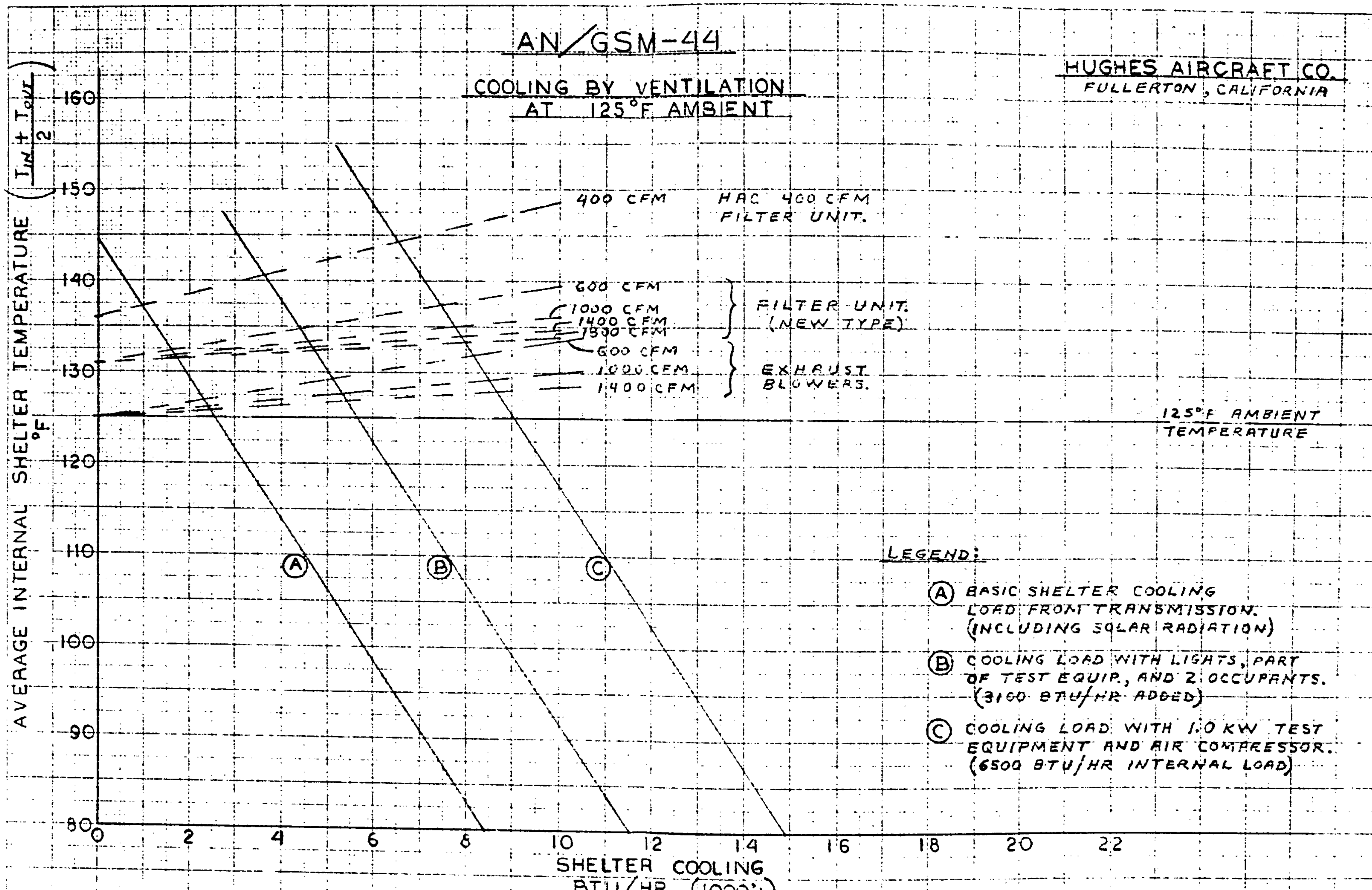

AN/GSM-44
COOLING BY VENTILATION
AT 125°F AMBIENT
HUGHES AIRCRAFT CO.
FULLERTON, CALIFORNIA
400 CFM
HAC 400 CFM FILTER UNIT.
600 CFM
1000 CFM
1400 CFM
1800 CFM
FILTER UNIT. (NEW TYPE)
600 CFM
1000 CFM
1400 CFM
EXHAUST BLOWERS.
125°F AMBIENT TEMPERATURE
A
B
C
LEGEND:
A BASIC SHELTER COOLING LOAD FROM TRANSMISSION. (INCLUDING SOLAR RADIATION)
B COOLING LOAD WITH LIGHTS, PART OF TEST EQUIP., AND 2 OCCUPANTS. (3100 BTU/HR ADDED)
C COOLING LOAD WITH 1.0 KW TEST EQUIPMENT AND AIR COMPRESSOR. (6500 BTU/HR INTERNAL LOAD)
AVERAGE INTERNAL SHELTER TEMPERATURE $\left(\frac{T_{IN} + T_{OUT}}{2}\right)$ °F
160
150
140
130
120
110
100
90
80
0
2
4
6
8
10
12
14
16
18
20
22
SHELTER COOLING BTU/HR (1000's)

FIGURE 1.

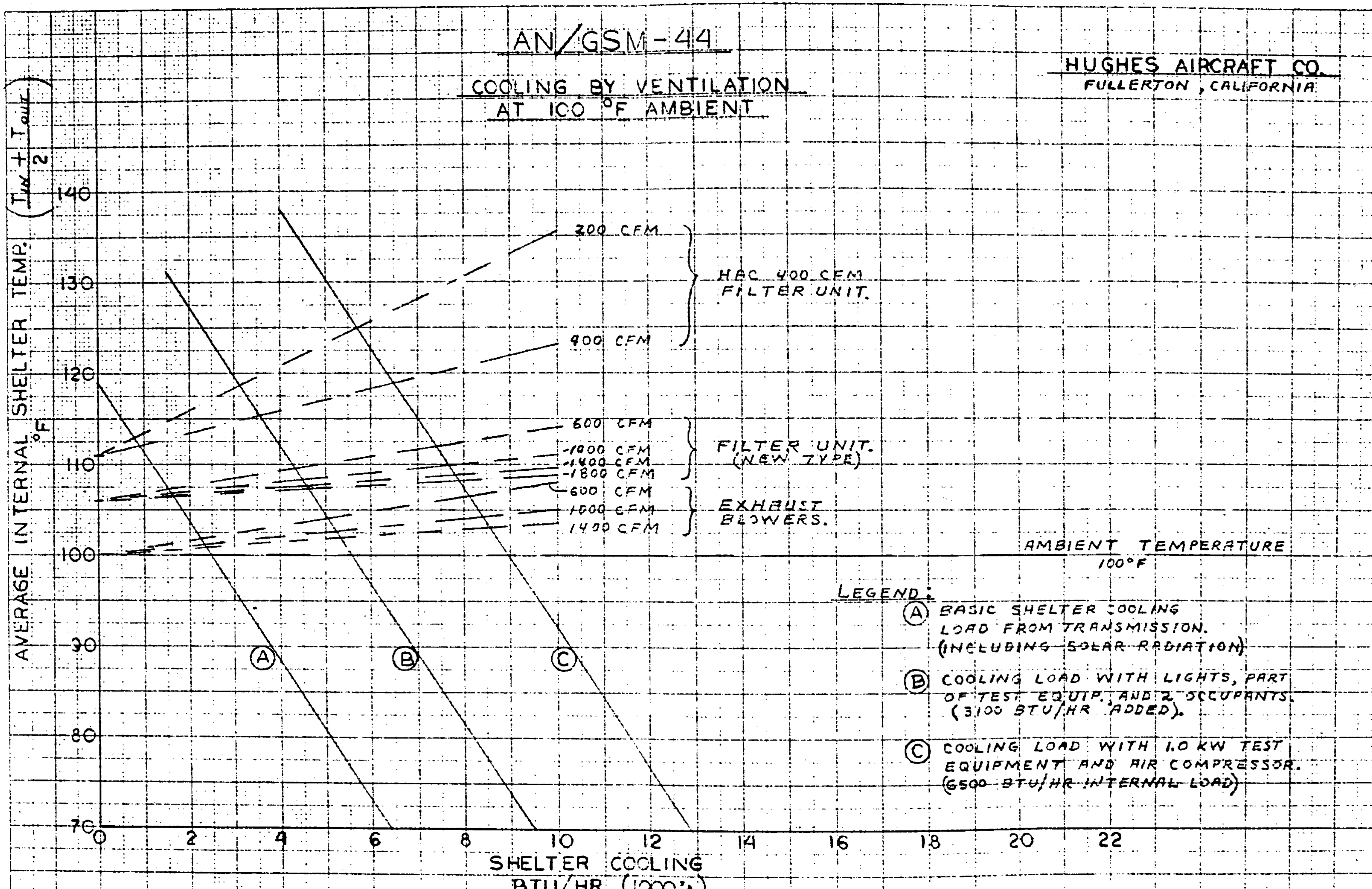

AN/GSM-44
COOLING BY VENTILATION
AT 100 °F AMBIENT
HUGHES AIRCRAFT CO.
FULLERTON, CALIFORNIA
AVERAGE INTERNAL SHELTER TEMP. °F
$\left(\frac{T_{in} + T_{out}}{2}\right)$
140
130
120
110
100
90
80
70
0
2
4
6
8
10
12
14
16
18
20
22
SHELTER COOLING
BTU/HR. (1000's)
200 CFM
400 CFM
HAC 400 CFM
FILTER UNIT.
600 CFM
1000 CFM
1400 CFM
1800 CFM
FILTER UNIT.
(NEW TYPE)
600 CFM
1000 CFM
1400 CFM
EXHAUST
BLOWERS.
AMBIENT TEMPERATURE
100°F
A
B
C
LEGEND:
A BASIC SHELTER COOLING LOAD FROM TRANSMISSION. (INCLUDING SOLAR RADIATION)
B COOLING LOAD WITH LIGHTS, PART OF TEST EQUIP., AND 2 OCCUPANTS. (3100 BTU/HR ADDED).
C COOLING LOAD WITH 1.0 KW TEST EQUIPMENT AND AIR COMPRESSOR. (6500 BTU/HR INTERNAL LOAD)

FIGURE 2.

as follows:

PART LOAD (CURVE B)		WATTS	BTU/Hr.
Lights		210	715
Part of Test Equipment		550	1885
Occupants (Sensible Heat)		---	500
	TOTAL		3100
FULL LOAD (CURVE C)			
All Test Equipment		1000	3400
Lights		210	715
Air Compressor		550	1885
Occupants (Sensible Heat)		---	500
	TOTAL		6500 BTU/Hr.

Consequently curves A, B, and C indicate the amount of heat which must be removed from the shelter with and without internal heat dissipation (personnel latent load and ventilation load omitted) to maintain various temperatures inside the shelters.

3. The remaining curves on Figures 1 and 2 provide an indication of the amount of heat which can be picked up by ventilating air flowing through the shelter. For this plot it was assumed that internal shelter temperature would be a mean temperature between inlet air and discharge air conditions. At the point where the ventilation air curves intersect the cooling load curves (A, B, and C), the cooling load (heat which must be removed) balances the amount of heat picked up by ventilation air. Reading to the left, one can determine the average temperature in the

shelter to maintain this balance. For example on Figure 1 Curve C intersects the 600 cfm exhaust blower curve at temperature of 131.8 °F, indicating that a 600 cfm airflow through the operating AN/GSM-44 shelter/system when moved by exhaust blowers will maintain that average internal temperature.

4. The enclosed Table I illustrates average internal temperatures to be expected using the two exhaust blowers provided in the shelter. (Reference Figures 1 and 2). Also included in the table are ventilating air inlet and outlet temperatures. It should be noted that personnel working in the shelter could be subjected to a wide variety of temperatures ranging from the inlet temperature to the discharge temperature. For example if personnel happened to be near the air inlet, in a relatively drafty location, they might be surrounded by air at outside ambient temperature. However if they happened to be out of the inlet draft and are in a location subject to the heat from equipment, radiation from the warm walls and ceiling, or near the exhaust blowers, the temperature surrounding the personnel will be most probably between the average (MEAN) temperature and the discharge temperature. Data for airflow rates of 600 and 1000 cfm are most probably representative of conditions to be expected in shelters without CPE.

5. From the data discussed above, it can be readily observed that personnel working in the AN/GSM-44 shelters are subjected to critical heat conditions when the equipment is operating, and the outside ambient temperatures are 100° F and above.

TABLE I

AN/GSM-44 COOLING WITH SHELTER EXHAUST BLOWERS

	CONDITION	Ambient Air Temp. °F	Total Airflow CFM	Air Inlet Temp. °F	Avg Internal Temp. °F	Air Discharge Temp. °F
1.	AN/GSM-44	100	1400	100	100.9	101.7
	with no	100	1000	100	101.2	102.3
	Internal	100	600	100	101.6	103.1
	Loads	125	1400	125	125.9	126.8
		125	1000	125	126.2	127.5
		125	600	125	127.0	129.0
2.	AN/GSM-44	100	1400	100	103	106
	with full	100	1000	100	104.2	108.4
	Internal	100	600	100	106.6	113.2
	Loads	125	1400	125	128.1	131.3
	(7500 BTU/Hr.)	125	1000	125	129.3	133.7
		125	600	125	131.9	138.8
3.	AN/GSM-44	100	1400	100	101.8	103.7
	with Part	100	1000	100	102.6	105.2
	Loads	100	600	100	104.1	108.3
	(3100 BTU/Hr.)	125	1400	125	126.9	128.9
		125	1000	125	127.7	130.4
		125	600	125	129.3	133.7

B. <u>Operating Conditions with Collective Protection Equipment</u> (No Air Conditioning).

1. When a CB Filter Unit is used to ventilate shelters/systems such as the AN/GSM-44, the already critical internal temperatures are not necessarily aided, even by large volumes of circulating air, inasmuch as the Filter Unit causes an increase in the temperature of air delivered to the shelter. For example the HAC developed 400 cfm Filter Units (two models) have consistently caused 9 to 11°F temperature rise in the air stream because of the pressure rise in the blower. These units have a higher delivery pressure than required for the system under study. However, it was estimated that a new type high capacity filter unit designed especially for ventilating the subject shelters would cause a temperature rise of approximately 6°F minimum under full flow conditions.

2. Cooling conditions using ventilating air from a CB Filter Unit are plotted also on Figures 1 and 2. Curves in both figures show the cooling obtained with ventilation rates of 1800 cfm, 1400 cfm, 1000 cfm, and 600 cfm respectively. As previously described, the point of intersection of these curves with the shelter total cooling load curve occurs at the average internal shelter temperature. Temperatures expected in the shelters with a high capacity filter unit are tabulated in Table II. Curves of Figures 1 and 2, and data also tabulated in Table II show temperatures expected using 200 or 400 cfm of air from HAC Filter Unit PN 1530300-100.

3. As shown by the Figures and Tables, the internal temperatures of both shelters are generally raised several degrees at comparable ambient conditions and internal loads when using a CB Filter Unit for summer cooling. Previous comments of Section I-A regarding the actual temperature of the air surrounding personnel also apply to this mode of operation. The following conclusions are drawn:

   a) With internal heat loads in the shelters, the internal temperatures at ambients of 100°F or above are excessive and it is highly unlikely that operators could perform their mission for more than short time periods, even with high ventilation rates.

   b) Use of the HAC 400 cfm unit for summer cooling of the subject shelters is not practical except at ambient temperatures below approximately 75°F, with the full rated output of the filter unit passing through the shelter.

TABLE II

AN/GSM-44 COOLING WITH CB FILTER UNIT

CONDITION	Ambient Air Temp. °F	Airflow CFM	Air Inlet Temp. °F	Avg. Internal Temp. °F	Air Discharge Temp. °F
1. AN/GSM-44 with no Internal Loads	100	1800	106	106.4	106.9
	100	1400	106	106.6	107.1
	100	1000	106	106.8	107.6
	100	600	106	107.3	108.5
	125	1800	131	131.5	132.0
	125	1400	131	131.6	132.2
	125	1000	131	131.8	132.7
	125	600	131	132.3	133.7
	100	400	111	112.1	113.2
	100	200	111	112.8	114.7
	125	400	136	137.2	138.4
2. AN/GSM-44 with part Internal Loads (3100 BTU/Hr.)	100	1800	106	107.2	108.5
	100	1400	106	107.6	109.2
	100	1000	106	108.2	110.4
	100	600	106	109.6	113.1
	125	1800	131	132.3	133.7
	125	1400	131	132.7	134.4
	125	1000	131	133.3	135.7
	125	600	131	134.7	138.5
	100	400	111	115.3	119.7
	100	200	111	118.6	126.2
	125	400	136	140.6	145.2
3. AN/GSM-44 with full Loads (6500 BTU/Hr.)	100	1800	106	108.2	110.3
	100	1400	106	108.7	111.4
	100	1000	106	109.8	113.5
	100	600	106	112.0	118.0
	125	1800	131	133.3	135.5
	125	1400	131	133.9	136.8
	125	1000	131	135.0	139.0
	125	600	131	137.3	143.7
	100	400	111	119.0	127.0
	100	200	111	125.0	139.0
	125	400	136	144.3	152.6

C. Cooling Requirements With Air Conditioning And Collective Protection Equipment

1. If air conditioning equipment is used to maintain reasonable internal temperatures in the AN/GSM-44 Shelters while operating at high ambient temperatures, the CB Filter Unit will then be sized to satisfy only the system ventilation or air leakage requirements of the shelter and CPE System, and to furnish adaquate scavenge air to the Protective Entrance. These systems can be arranged quite similarly to those previously developed for the AN/TSQ-38 and RTS Shelters in which approximately 150 cfm of air from the 400 cfm CB Filter Unit is ducted directly to the air conditioner, and approximately 250 cfm of air bypasses the shelter air circulating/cooling system and flows directly from the Filter Unit to the Protective Entrance.

2. Calculations have been made of the amount of cooling required to maintain a maximum average temperature of 85°F in the subject shelters when operating in extremely hot desert conditions of 125°F db and 90°F effective temperature (75°F wb), and summer humid conditions of 100°F db and 90°F effective temperature (86°F wb), with 150 cfm of makeup air supplied by a CB Filter Unit. Results are included in Table III. The humid condition cooling requirement is slightly higher than that at hot desert conditions. However, in selection of an air conditioner it is generally found that the hot

desert condition requirement is the governing factor, as a unit which will meet this requirement will usually exceed the humid condition requirement.

3. The data of Table III indicates that a unit capable of two tons refrigeration (24000 BTU/Hr.) at the hot-desert ambient conditions, with 85°F return air, would suffice for AN/GSM-44 shelters when operating with Collective Protection Equipment. Without Collective Protection Equipment, over 0.5 ton refrigeration (6000 BTU/Hr) could be deducted from the air conditioning requirement because of the reduced ventilation rates and lower vent air inlet temperatures.

TABLE III

COOLING REQUIREMENTS OF AN/GSM-44 SHELTER
WITH COLLECTIVE PROTECTION EQUIPMENT

CONTRIBUTION TO COOLING LOAD	COOLING LOAD	
	Desert Condition 125°F db 75°F wb	Humid Condition 100°F db 86°F wb
	BTU/Hr.	BTU/Hr.
Roof, Wall, Floor Heat Transmission -(Including Solar Radiation)	7750	4500
Occupants (2)	1000	1000
Test Equipment, Air Compressor and Lights	6000	6000
Ventilation (Maximum Air Leakage of 150 cfm at Internal Density, and Supplied at 10°F above Ambient Temperature).	7900	15100
TOTAL	22650	26600
% SENSIBLE HEAT	97.8	71.0

NOTES:

1. Based on use of Air Conditioner which recirculates all air except that lost by CPE Shelter/System leakage.
2. Assumed: That average internal temperature is 85°F, and return air and air lost by leakage is approximately 85°F. Also assumed air density at internal conditions.

SECTION II

AN/GSM-44 SYSTEM

WINTER OPERATION

A. Existing Internal Conditions Without Collective Protection.

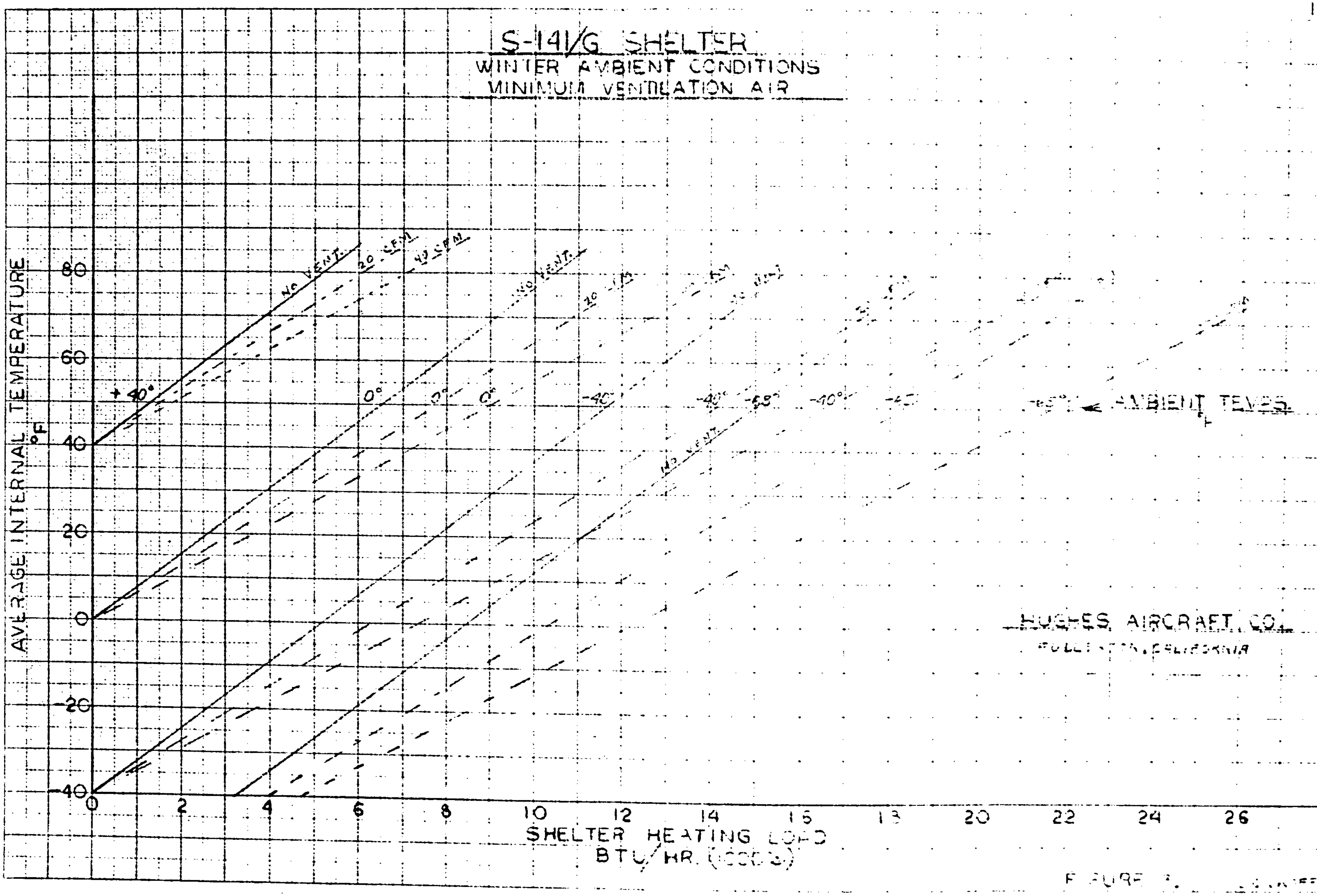
B. Operating Conditions with Collective Protection Equipment and Existing Heating Units.

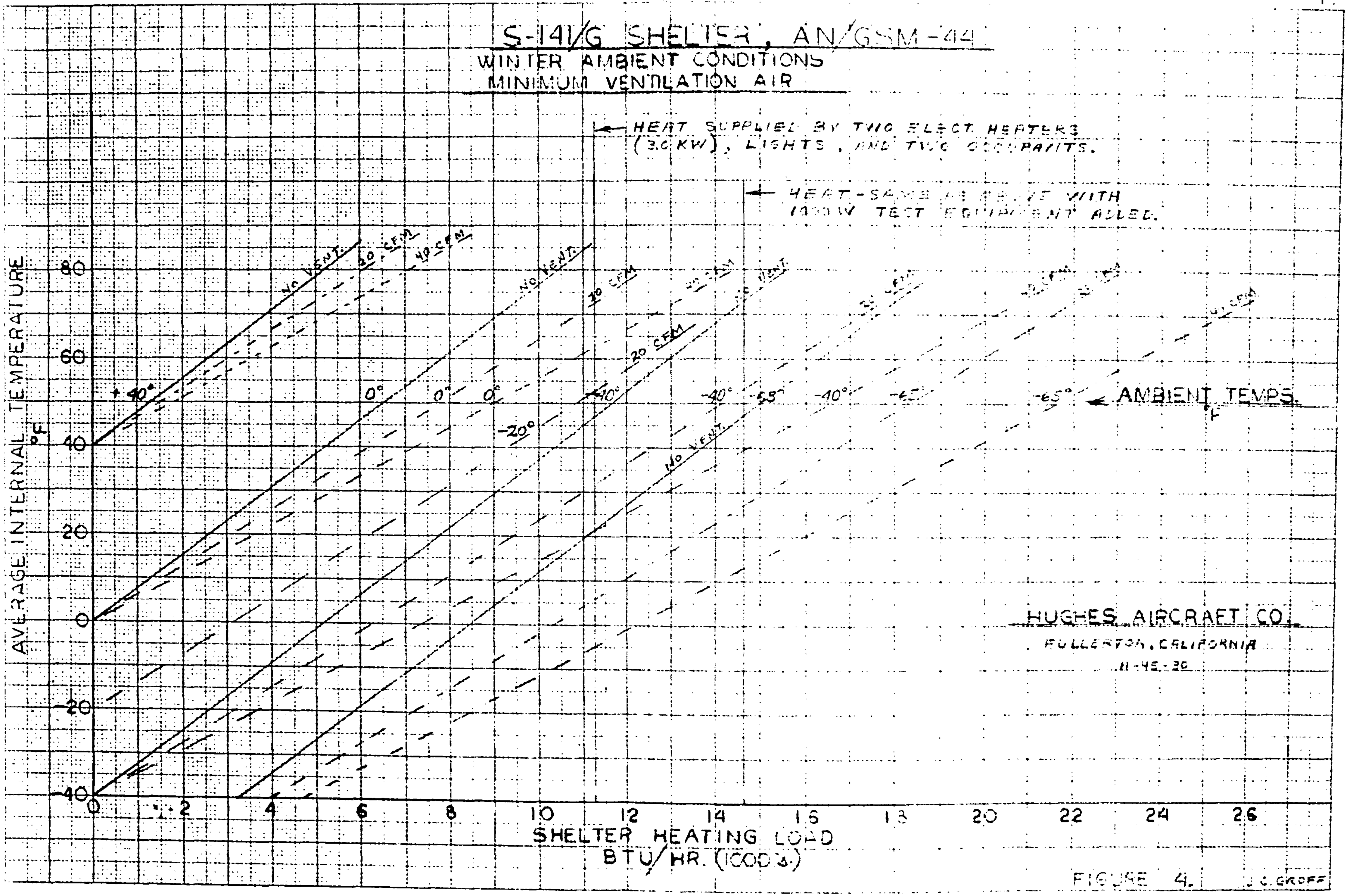
C. Heating Requirements with Collective Protection Equipment.

A. <u>Existing Internal Conditions Without Collective Protection Equipment</u>.

1. Calculations have been made for the heat losses of S-141/G Shelters which house the AN/GSM-44 Systems. Data has been plotted on Figure 3 to show heat losses at various ambient temperatures, at ventilation rates of 0, 20, and 40 cfm (outside densities). This figure can be used in two manners. First, it can be used to determine a heating requirement if the ambient temperature and ventilation rate are known. Secondly it can be used to estimate internal temperatures of the shelter at various ambients if the heat input is known.

2. Curve Sheet Figure 4 was made to show internal conditions of the subject shelters at various ambients and equipment operating conditions, assuming that ventilation air is maintained at 20 cfm, which is less than the minimum recommended for two persons. Data in Table IV, as taken from Figure 4, indicates that the shelters with test equipment not operating are insufficiently heated at ambient temperatures of -20°F or lower. With test equipment operating, the ambient temperature can decrease to -40°F before temperatures could be termed critical for the inside. The expression "ok" in the table indicates that temperatures above 60°F can be maintained in the shelter, and at these conditions, temperature control of the shelter can be accomplished by shutting off the heater intermittently and/or by increasing the intake of ventilating air into the shelter.


S-141/G SHELTER
WINTER AMBIENT CONDITIONS
MINIMUM VENTILATION AIR
AVERAGE INTERNAL TEMPERATURE °F
80
60
40
20
0
-20
-40
0
2
4
6
8
10
12
14
NO VENT.
20 CFM
40 CFM
+40°
0°
-40°
AMBIENT TEMPS.
HUGHES AIRCRAFT CO.
SHELTER HEATING LOAD
BTU/HR.



S-141/G SHELTER, AN/GSM-44
WINTER AMBIENT CONDITIONS
MINIMUM VENTILATION AIR
HEAT SUPPLIED BY TWO ELECT. HEATERS (3.0 KW), LIGHTS, AND TWO OCCUPANTS.
HEAT - SAME AS ABOVE WITH 1500 W TEST EQUIPMENT ADDED.
AVERAGE INTERNAL TEMPERATURE °F
SHELTER HEATING LOAD BTU/HR. (1000's)
AMBIENT TEMPS. °F
NO VENT.
20 CFM
40 CFM
+40°
0°
-20°
-40°
-65°
80
60
40
20
0
-20
-40
2
4
6
8
10
12
14
16
18
20
22
24
26
HUGHES AIRCRAFT CO.
FULLERTON, CALIFORNIA

FIGURE 4.

TABLE IV

AN/GSM-44 INTERNAL TEMPERATURES

(Without CPE)

Condition	Ambient Temperature °F	Internal Temperature °F
1. AN/GSM-44 Shelter with heaters and lights on, but no other equipment operating. (3.0 KW heat., 160 W lights, and 2 occupants @ 11250 BTU/Hr.).	+40	ok
	0	ok
	-20	53
	-40	31
	-65	+6
2. Same as above with 1.0 KW test equipment added. (14660 BTU/Hr. Total)	-20	ok
	-40	53
	-65	27

NOTES: 1. "ok" indicates that a temperature of 60°F or above can be maintained in the shelter.

2. Assumed ventilation rate of 20 cfm at outside densities.

B. Operating Conditions with Collective Protection Equipment and Existing Heaters.

1. The effect of increasing the S-141/G Shelter ventilation air flow rate at low ambient temperatures is illustrated by Figure 5. Data for this figure was calculated assuming that the flow rate (and air density) are at sea level outside ambient conditions, and the air is heated approximately 8°F by the Filter Unit. This figure can also be used in the two manners described in Section II A. The figure demonstrates that for winter operations the shelter heating requirements are minimum when the ventilation rate is held to the minimum. Heat inputs to the shelters under various operating conditions are plotted on a similar curve sheet, Figure 6.

2. The data on Table V was derived assuming that an air leakage rate of 100 cfm maximum can be maintained in the shelters when pressurized by CPE. The data indicates that the subject shelters will be insufficiently heated at ambient temperatures of 0°F and below when no test equipment is operating.

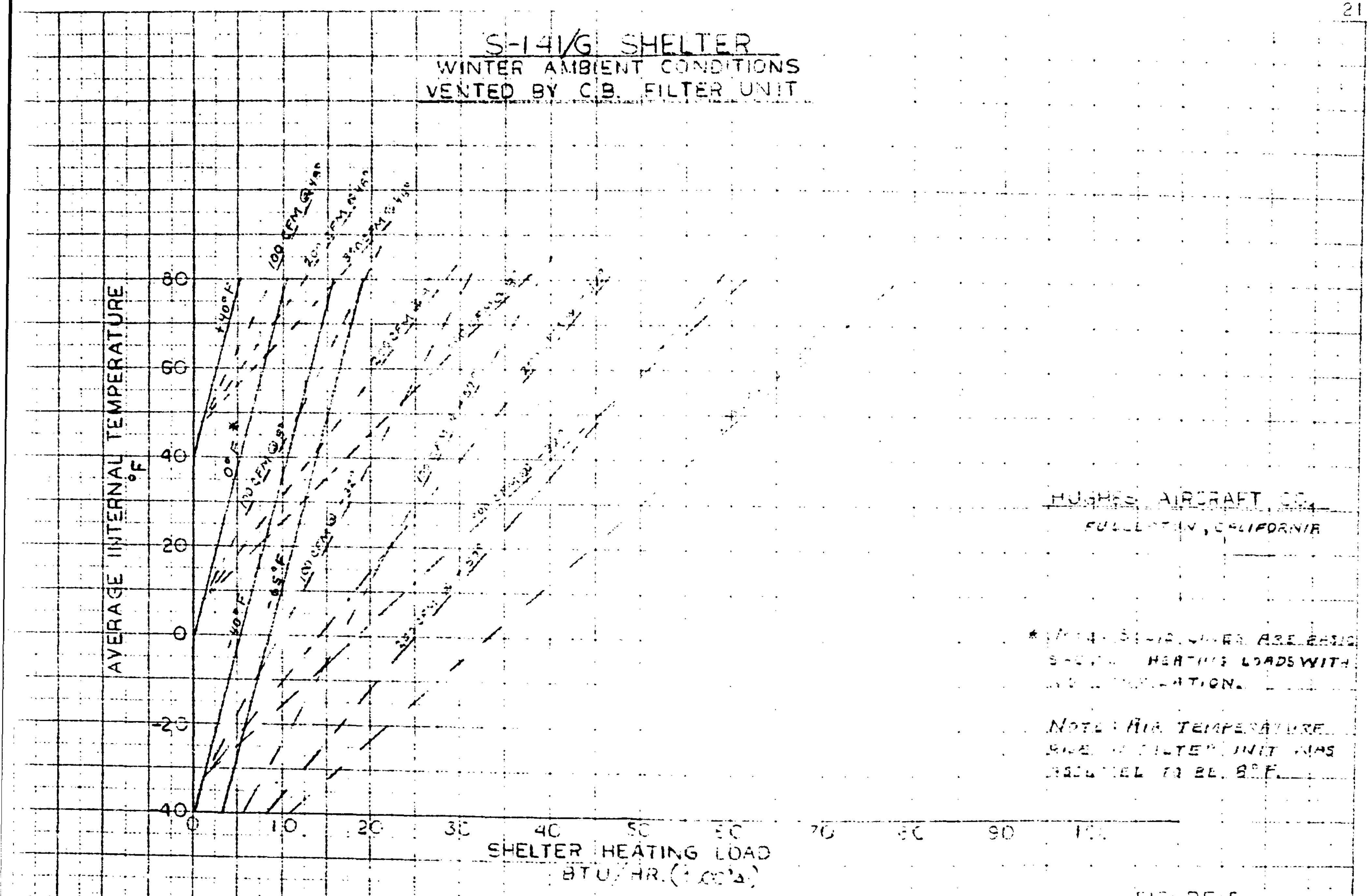

S-141/G SHELTER
WINTER AMBIENT CONDITIONS
VENTED BY C.B. FILTER UNIT
AVERAGE INTERNAL TEMPERATURE °F
80
60
40
20
0
-20
-40
0
10
20
30
40
50
70
90
SHELTER HEATING LOAD
BTU/HR.
+40°F
0°F *
-40°F
-65°F
100 CFM
HUGHES AIRCRAFT CO.
FULLERTON, CALIFORNIA
NOTE: AIR TEMPERATURE
TO BE 8°F.

FIGURE 5.

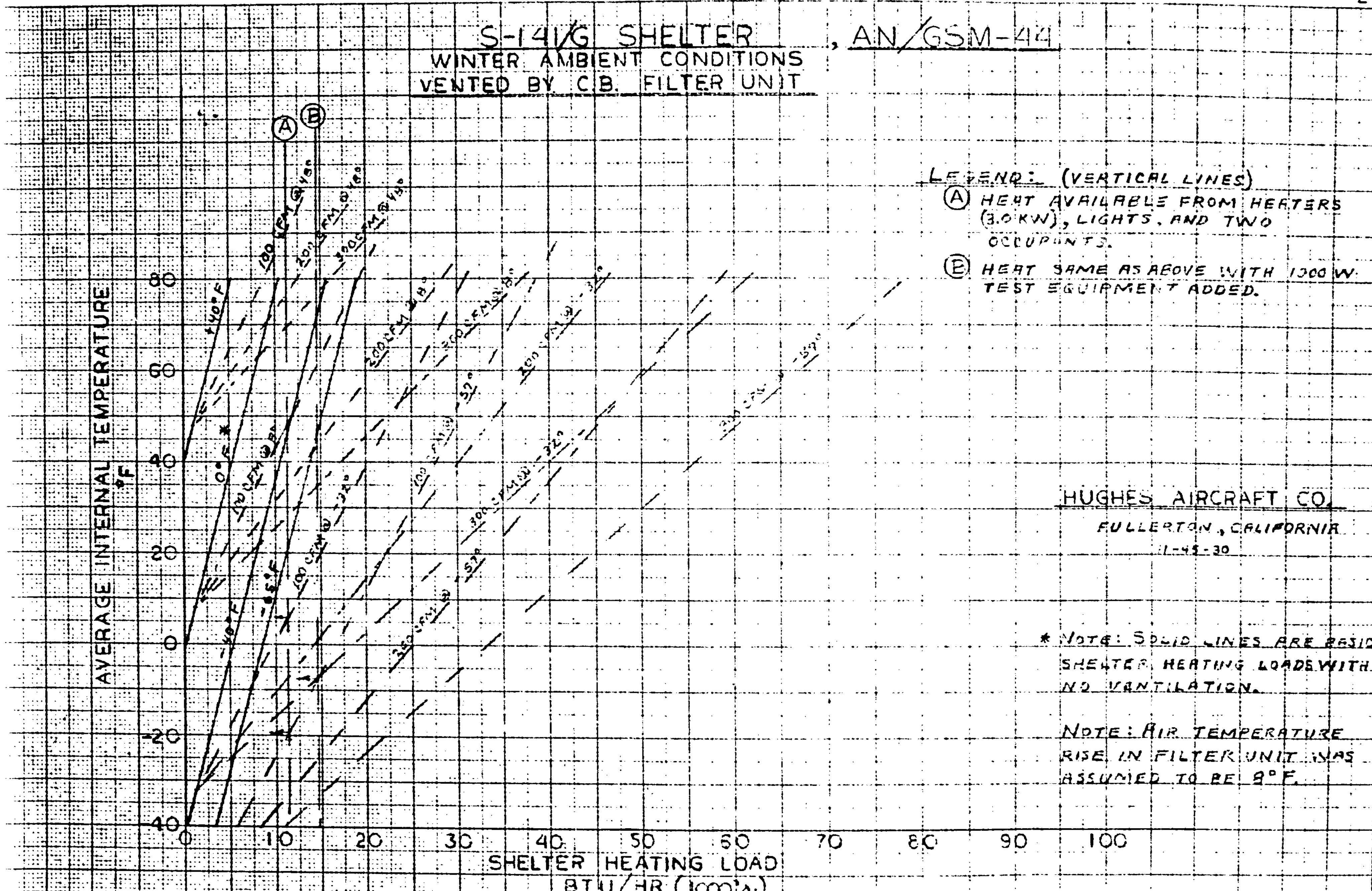

S-141/G SHELTER, AN/GSM-44
WINTER AMBIENT CONDITIONS
VENTED BY C.B. FILTER UNIT
LEGEND: (VERTICAL LINES)
(A) HEAT AVAILABLE FROM HEATERS (3.0 KW), LIGHTS, AND TWO OCCUPANTS.
(B) HEAT SAME AS ABOVE WITH 1300 W. TEST EQUIPMENT ADDED.
HUGHES AIRCRAFT CO.
FULLERTON, CALIFORNIA
* NOTE: SOLID LINES ARE BASIC SHELTER HEATING LOADS WITH NO VENTILATION.
NOTE: AIR TEMPERATURE RISE IN FILTER UNIT WAS ASSUMED TO BE 9°F.
AVERAGE INTERNAL TEMPERATURE °F
SHELTER HEATING LOAD BTU/HR. (1000's)
+40°F
0°F
-40°F
-65°F
100 CFM @ 48°
200 CFM @ 48°
300 CFM @ 48°
0
10
20
30
40
50
60
70
80
90
100
80
60
40
20
0
-20
-40

FIGURE 6.

TABLE V

AN/GSM-44 INTERNAL TEMPERATURES

(Using CB Filter Unit)

	Condition	Ambient Temperature °F	Internal Temperature °F
1.	AN/GSM-44 Shelter, with heaters and lights on but no other equipment operating. (11250 BTU/Hr. Heat Input)	+40	ok
		+20	ok
		0	48
		-40	+6
		-65	-19
2.	Same as above, with 1.0 KW Test Equipment operating (14660 BTU/Hr. Heat Input)	0	61 (ok)
		-20	41
		-40	+20
		-65	-7

Assumed: Ventilation rate of 100 CFM (outside densities) with air heated 8°F by Filter Unit.

C. <u>Heating Requirement With Collective Protection Equipment</u>.

1. The heating requirement of the S-141/G shelters is increased considerably when Collective Protection Equipment is added and the ventilation rate is increased. For example at -65°F ambient without CPE (ventilation rate of 20 cfm), the heating requirement for 60°F inside temperature is 19900 BTU/Hr. With CPE and a ventilation rate of 100 cfm, the heating requirement will be 33000 BTU/Hr., an increase of 66%. If an air leakage of 50 cfm could be obtained by careful sealing of the shelter, the heating requirement would then be reduced to 24500 BTU/Hr. at -65°F outside ambient and +60°F inside. This is still an increase of 23% over the requirement without CPE.

2. So that the AN/GSM-44 Systems can be adequately heated when test equipment is not in use, it is recommended that heating units with the following capacities be provided when Collective Protection Equipment is used with the subject shelters:

For Ambients Down To -40°F -

Heater(s) with output of 25500 BTU/Hr.
(7.5 KW if electrical)

For Ambients Down To -65°F -

Heater(s) with output of 33000 BTU/Hr.
(9.67 KW if electrical).

SECTION III

APPROACHES FOR SATISFACTORY SHELTER INTERNAL CONDITIONS AT SUMMER AND WINTER AMBIENT EXTREMES.

A. 400 CFM CB Filter Unit with Auxiliary Heating-Cooling. 27

B. High Capacity Filter Unit - with P. E. scavenge air routed through shelter. 34

C. High Capacity Filter Unit - with P. E. scavenge air bypassing shelter, and heat supplied to shelter. 39

D. High Capacity Filter Unit - with P. E. scavenge air bypassing shelter. (No auxiliary heating). 44

E. 400 CFM Filter Unit. 47

SECTION III

APPROACHES FOR SATISFACTORY SHELTER INTERNAL CONDITIONS AT SUMMER AND WINTER AMBIENT EXTREMES

1. From the data presented and discussed in Sections I and II it is obvious that the AN/GSM-44 Systems with or without Collective Protection Equipment should be provided additional heating - cooling equipment. This is necessary for maintaining reasonable and satisfactory internal temperatures when operating at ambient temperature extremes below -20°F and above 100°F. Temperatures in the range of 60°F minimum (during winter) to 85°F maximum (during summer) would allow personnel assigned to the AN/GSM-44 to perform their mission of servicing and checkout of complex electronic equipment with best efficiency. To maintain these temperatures while using a Collective Protection System will require slightly higher capacity heating and cooling units than required without CPE.
2. Outlined and illustrated in the following discussions are approaches which could be used while providing Collective Protection to the AN/GSM-44. Only the first approach is termed satisfactory for all ambient temperature extremes. Two other approaches would give reasonable working conditions at all ambients except above approximately 85°F ambient temperature, and are recommended for use only with limitations on usage within the ambient temperature range of -65°F to +85°F. The last two approaches are very limited and not recommended by HAC in view of the ambient temperature limitations.

APPROACH A

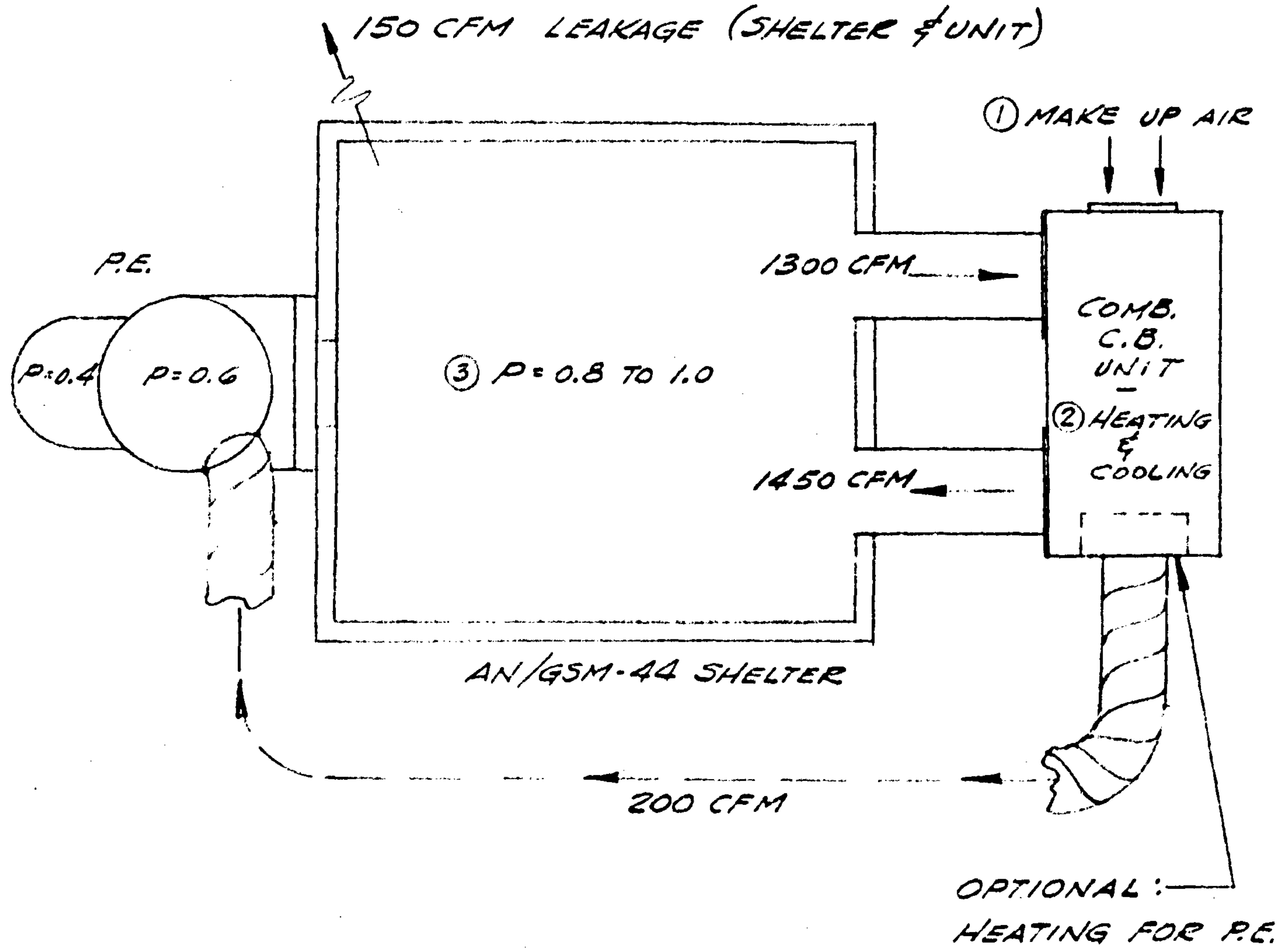
400 CFM CB FILTER UNIT WITH AUXILIARY HEATING - COOLING

Reference: Figure 7

DESCRIPTION

1. This approach employs a cooling-heating unit (herein called "The Unit"), which recirculates all air except that which is lost by air leakage (or minimum ventilation requirements). The unit employs CB Filter Unit components which filter the makeup and P.E. scavenge air and supply it at a pressure suitable for maintaining all areas of the shelter/CPE/air circulating system at a suitable pressure (0.5 inches w.g. minimum) higher than atmospheric pressure. C.B. Filter Unit components of a nominal 400 CFM capacity will suffice. Approximately 150 cfm of filtered air is ducted directly to the circulating blower inlet chamber, and 200 cfm is delivered to the Protective Entrance via an external duct.
2. The cooling capacity of the Unit, if considering only the AN/GSM-44 System, should be a minimum of 2 tons refrigeration when rated at 125°F ambient with 85°F return air and 100 percent sensible heat. However, usage of a 3 ton unit (36000 BTU/Hr.) will enable this unit to also support the AN/MRC-69, and usage of a 3.75 to 4.0 ton unit (45000 BTU/Hr.) would extend the capacity range to also support the AN/GSS-1 System.

APPROACH "A"



① MAKE UP AIR (APPROX. 350 CFM):
200 CFM FILTERED AIR DUCTED TO P.E.
150 CFM FILTERED AIR ADDED TO A.C. SHELTER SYSTEM

② HEATING COOLING IS ONLY FOR AIR CIRCULATING TO SHELTER

③ P = PRESSURE (INCHES W.G.)

FIGURE 7.

3. Heating capacity of the unit should be a minimum of 33000 BTU/Hr. (approximately 10 KW) if all heating of the system is accomplished without the use of the heaters provided in the shelters. This approach is recommended in order to provide the most practical methods of system operation and temperature control. However, if the shelter internal heaters are utilized the heating capacity of the Unit could be reduced by the amount available in the shelters. The heating capacity recommended above will support the AN/GSS-1, AN/GSS-7, AN/GSM-44, AN/MRC-69 and AN/MRC-73 Systems, and possibly others lacking the proper equipment.

EQUIPMENT OPTIONS

1. The Unit can be of two types, either a set of components integrated into one common enclosure, or a combination of an existing CB Filter Unit and an available air conditioner-heater mounted on a common skid, utility trailer, or truck chassis. The first unit configuration would have the advantages of lower manufacturing cost and a less cumbersome overall package. If the second configuration is utilized, it is recommended that operating controls of the air conditioner, heater, and CB Filter Unit be consolidated into a common Control Box for use inside the shelter, in order to simplify cabling which must pass through the shelter wall from the Unit to the control area, and to conserve space inside the shelter.

2. In order to provide the best possible scavenging of contaminants from the protective entrance, and to assist in personnel decontamination therein, HAC recommends that air to the protective entrance be heated during severe winter operations of the CPE system. Approach A does not pass protective entrance air through the shelter inasmuch as the cooling requirement for summer operation would be greatly increased, and protective entrance cooling is deemed unnecessary. Heating the 200 cfm of scavenge air would require a capacity of 50,000 BTU/Hr. (14.65 KW) to deliver air at slightly above 100°F ambient.
3. Power for the Unit could be furnished from an external source if an all electric configuration is selected, However, it would be possible and practical to develop an engine driven unit which is completely self contained and requires no external power. The engine driven configuration would utilize a liquid fuel burning heater (or possibly exhaust heat exchanger), and direct or low temperature belt drive of the blowers and other rotating components (no motors). A heavy duty direct driven generator would be utilized to furnish power for battery charging and controls used throughout the unit.
4. The Unit can be assembled on a skid. However, for optimum transportation of the Unit, all associated CPE accessories, and the Protective Entrance, HAC recommends mounting all equipment and storage provisions on an integral chassis or a Government furnished vehicle, utility trailer, or small truck.

5. The new type combination unit (first configuration of Paragraph 1 above), can be developed with one additional feature used previously in HAC developed air conditioners for AN/MSQ-18 and AN/TSQ-38 Systems - that of cooling (with temperature control) without refrigeration when ambient temperatures are below approximately 65°F. This feature conserves power and equipment, and can be used when CB protection is not required. Temperature control is achieved automatically by mixing of heated return air and cold fresh ambient air in proper and various proportions to achieve the desired Unit delivery temperature.

CONTROL OF SYSTEM

1. The CPE System supported by the Unit of Approach A will be operated from inside the shelter by a Control Box serving the various units.
2. An automatic damper will regulate the Filter Unit air delivery to maintain the system pressure within the required limits. Also manual damper(s) will be provided to establish proper balance of the flows and pressures to the shelter and Protective Entrance.

POWER REQUIREMENTS

1. The estimated power requirements of the Unit, if all electric,

are approximately as shown on Table VI. Preliminary power requirements of an engine driven Unit are also shown, based upon the assumption that heaters used with this type unit will be of the liquid fuel burning or exhaust heat exchanger type.

ADVANTAGES (APPROACH A)

1. This approach provides complete Collective Protection and environmental control of shelters/systems which have insufficient cooling-heating equipment originally installed, at all ambient temperature extremes.
2. With equipment of this approach afforded proper mobility, the transportation of the complete CPE - environmental control system will be greatly enhanced.
3. With proper arrangement of controls, system setup and equipment operational requirements of the assigned personnel will be minimized.
4. The self contained configuration of the Unit described above will eliminate requirements for higher capacity generators when features of environmental control and Collective Protection are added to defense subsystems such as the AN/GSM-44 and other referenced herein.

TABLE VI

POWER REQUIREMENTS FOR APPROACH "A" UNIT

COMPONENTS	WINTER HEATING MODE	SUMMER COOLING MODE
A. For Conventional 3 ph, 60 cps Components:		
CB Filter Unit Blower	2.0 KW	1.85 KW
Cooling System (4 Ton Refrig. capacity - including circulating blower)	-	9.25 KW (Maximum)
Heating - To Shelter Only	10.0 KW	-
TOTAL	12.0 KW	11.1 KW
OPTIONAL:		
Added for Heating Scavenge Air to the Protective Entrance	14.65 KW	-
OPTIONAL TOTAL	26.65 KW	11.1 KW
B. For Light Weight 400 cps Components and Compact Heat Exchangers In Air Conditioner:		
Add to above:	0.5 KW	5.25 KW
TOTAL	12.5 KW	16.35 KW
OPTIONAL TOTAL	27.15	16.35 KW
C. For Engine Driven Components:		
Filter Unit Blower	2.5 BHP	2.2 BHP
Circulating Blower	1.0 BHP	1.0 BHP
Refrigeration System	-	8.25 BHP
Equipment Drives	2.0	1.5
Generator	1.0 BHP	1.0 BHP
TOTAL	6.5 BHP	13.95 BHP

APPROACH B

HIGH CAPACITY FILTER UNIT - WITH P. E. SCAVENGE AIR ROUTED THROUGH SHELTER

Reference: Figure 8

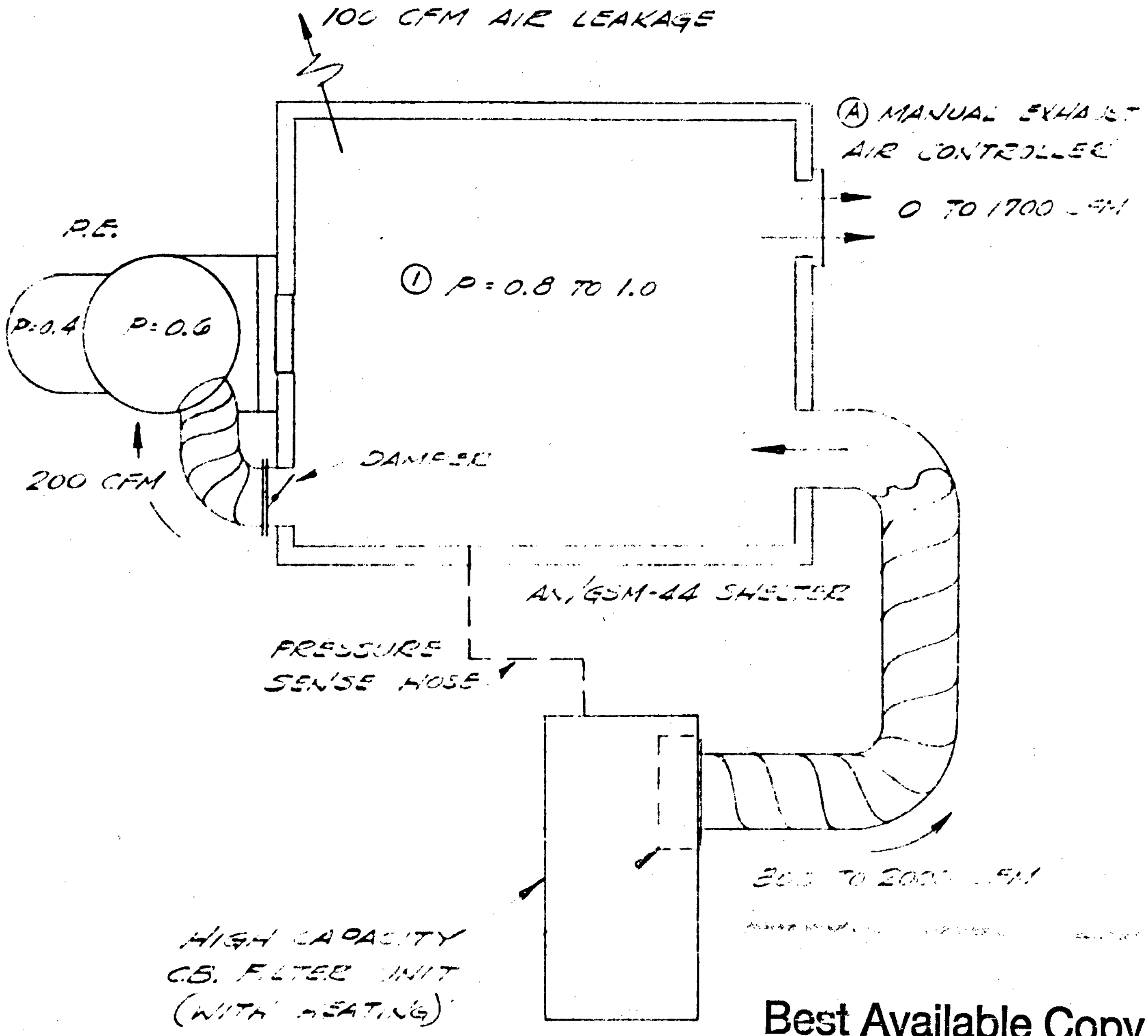
DESCRIPTION

1. Approach B employs a high capacity CB Filter Unit of 1200 to 200 cfm capacity which delivers all filtered air to the shelter. Air circulating through the shelter is discharged to the outside by two routes:

   a) Approximately 200 CFM is drawn from the shelter and is delivered via a duct to the top of the Protective Entrance for scavenging.

   b) The remaining air is discharged to the outside through a manually regulated exhaust air controller A (a variable damper and anti backdraft valve).

APPROACH "B"



① P = PRESSURE (INCHES W.G.)

FIGURE 8.

2. This Filter Unit utilizes an automatic damper system to regulate pressure inside the shelter within prescribed limits, and with constant pressure in the shelter, airflow to the Protective Entrance will remain fairly constant once the manual damper in the P. E. duct is adjusted for correct flow.
3. The Approach "B" Filter Unit must have a heater to replace or assist shelter heaters in maintaining reasonable temperatures during winter ambients. A heating capacity of 67000 BTU/Hr (19.65KW) is required to maintain 60°F inside the shelter when 300 CFM of air is delivered by the Filter Unit, and no internal heating equipment or electrical equipment is operating. At -65°F ambient the 300 CFM of air will be delivered to the shelter at approximately 98°F to maintain 60°F inside.

EQUIPMENT OPTIONS

The options (3 and 4) described for Approach "A" relative to power supply and transportation also apply to Approach "B".

CONTROL OF SYSTEM

1. This approach operates on the concept that the automatic damper in the Filter Unit will maintain a constant pressure in the shelter regardless of the air discharge rate through exhaust controller A.

POWER REQUIREMENTS

1. Following is an estimate of electrical power required for Approach B:

Component	Winter Heating Mode	Summer Cooling Mode
Blower		
300 CFM	2.5 KW	
2000 CFM		7.5 KW (max)
Heater	20.0 KW	None
Total	22.5 KW	7.5 KW

2. If an engine is utilized to drive this unit, approximately 8.5 Bhp are required winter or summer, with a liquid fuel burning heater.
3. For 1600 and 1200 CFM CB Filter Units, decrease summer cooling mode power requirements by 1.75 and 3.5 KW respectively.

ADVANTAGES (Approach B)

1. Simplicity of controls, mostly manual, could be provided with this approach.
2. In the summer operating mode, airflow through the shelter is at maximum, for lowest internal temperatures. Winter mode reduction of airflow does not cause system unbalance relative to the Protective Entrance pressure.
3. The Protective Entrance is partially heated, for improved scavenging and personnel decontamination. Air will enter the Protective Entrance at a minimum of approximately 60°F, and therefore impart some heat to the P.E. chambers.

<u>DISADVANTAGES</u> (Approach B)

1. This approach requires a higher capacity heater than Approach A unless the Protective Entrance heating option of Approach A is utilized. This approach also requires a higher heating capacity than Approach C to be discussed later herein.
2. This approach provides no firm control or reduction of internal shelter temperature at high ambient temperatures to reasonable values.
3. During summer operation the air routed to the Protective Entrance will be heated more than it would be if ducted directly to the P. E. For example:

   2000 CFM Unit - 4.5°F

   1600 CFM Unit - 6°F

   1200 CFM Unit - 8°F

   800 CFM Unit - 12°F

APPROACH C

HIGH CAPACITY FILTER UNIT - WITH P.E. SCAVENGE AIR BYPASSING SHELTER

Reference: Figure 9

DESCRIPTION

1. Approach C utilizes the same equipment as Approach B with the following exceptions:
   a) The 200 cfm of scavenge air is ducted directly from the Filter Unit to the Protective Entrance, and therefore bypasses the shelter at all times.
   b) The heater employed for air delivered to the shelter is lower capacity inasmuch as only approximately 100 cfm of air heating is required during winter operations. Required heater capacity is 25,500 BTU/Hr (7.5 KW).

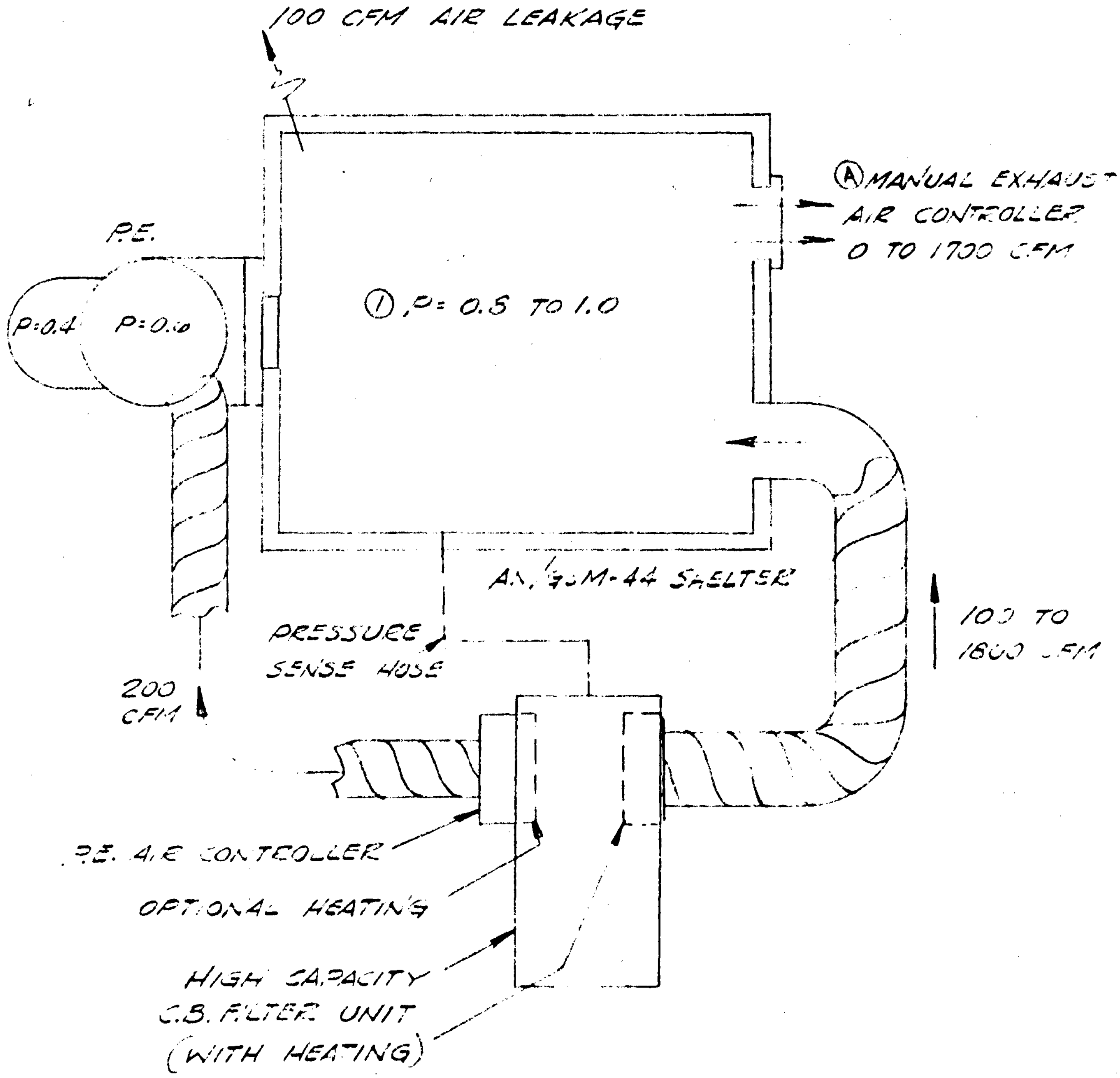
EQUIPMENT OPTIONS

1. Options 2, 3 and 4 of Approach A relative to P.E. heating, power supply, and transportation also apply to Approach C.

CONTROL OF SYSTEM

1. Temperature control inside the shelter is accomplished in the same manner described for Approach B.

APPROACH "C"



① P= PRESSURE (INCHES W.G.)

FIGURE 9.

2. This approach will require additional control of airflow and pressure to the Protective Entrance, because of the change in pressure drop of the shelter air delivery duct and fittings as flow rate varies from 100 to 1800 CFM. With constant shelter pressure the Filter Unit outlet plenum pressure will decrease as ventilation air rate is reduced, and therefore there will be less air delivered to the Protective Entrance during winter operations unless some form of control is provided. Two solutions exist for providing the control, as follows:

a) One approach would be to provide a volume flow regulator in the duct to the Protective Entrance to keep airflow rate relatively constant regardless of Filter Unit plenum pressure.

b) The alternate approach would utilize an automatic damper, which responds to P.E. internal pressure, in the duct or Filter Unit outlet provided for the Protective Entrance. This method will also keep airflow to the P.E. nearly constant.

POWER REQUIREMENTS

1. Following is an estimate of electrical power required for Approach C:

Component	Winter Heating Mode	Summer Cooling Mode
Blower		
300 CFM	2.5 KW	
2000 CFM		7.5 KW
Heater	7.5 KW	-
TOTAL	10.0 KW	7.5 KW
Optional: P.E. Heating	14.65	-
OPTIONAL TOTAL	24.65 KW	7.5 KW

2. If engine power is utilized, requirements are essentially the same as Approach B.

3. For 1600 and 1200 CFM CB Filter Units, decrease summer cooling mode power requirements by 1.75 and 3.5 KW respectively.

<u>ADVANTAGES</u> (Approach C)

1. This approach requires the lowest capacity heating equipment for winter operation, unless heat is provided for the Protective Entrance at low ambient temperatures.

<u>DISADVANTAGES</u> (Approach C)

1. Approach C does not reduce the critical summertime operating temperature inside the shelter to reasonable values.

2. This approach requires additional equipment (over Approach B) for maintaining system balance between the shelter and P.E. as ventilation rate is varied. (See CONTROL OF SYSTEM above.)

APPROACH D

HIGH CAPACITY FILTER UNIT - WITH P. E. SCAVENGE AIR BYPASSING SHELTER - NO AUXILIARY HEATING

Reference: Figure 10

DESCRIPTION

1. Same as Approach C except no heat is provided by the Filter Unit.

EQUIPMENT OPTIONS

1. Options 3 and 4 of Approach A relative to power supply and transportation also apply to Approach D.

CONTROL OF SYSTEM

1. Same as Approach C.

POWER REQUIREMENTS

1. Approach D utilizes power only for the blower and controls and would therefore be approximately 7.5 KW, or 8.5 Bhp (maximum for the summer mode). For 1600 and 1200 CFM CB Filter Units, power requirements will be approximately 5.75 and 4.0 KW respectively.

ADVANTAGES

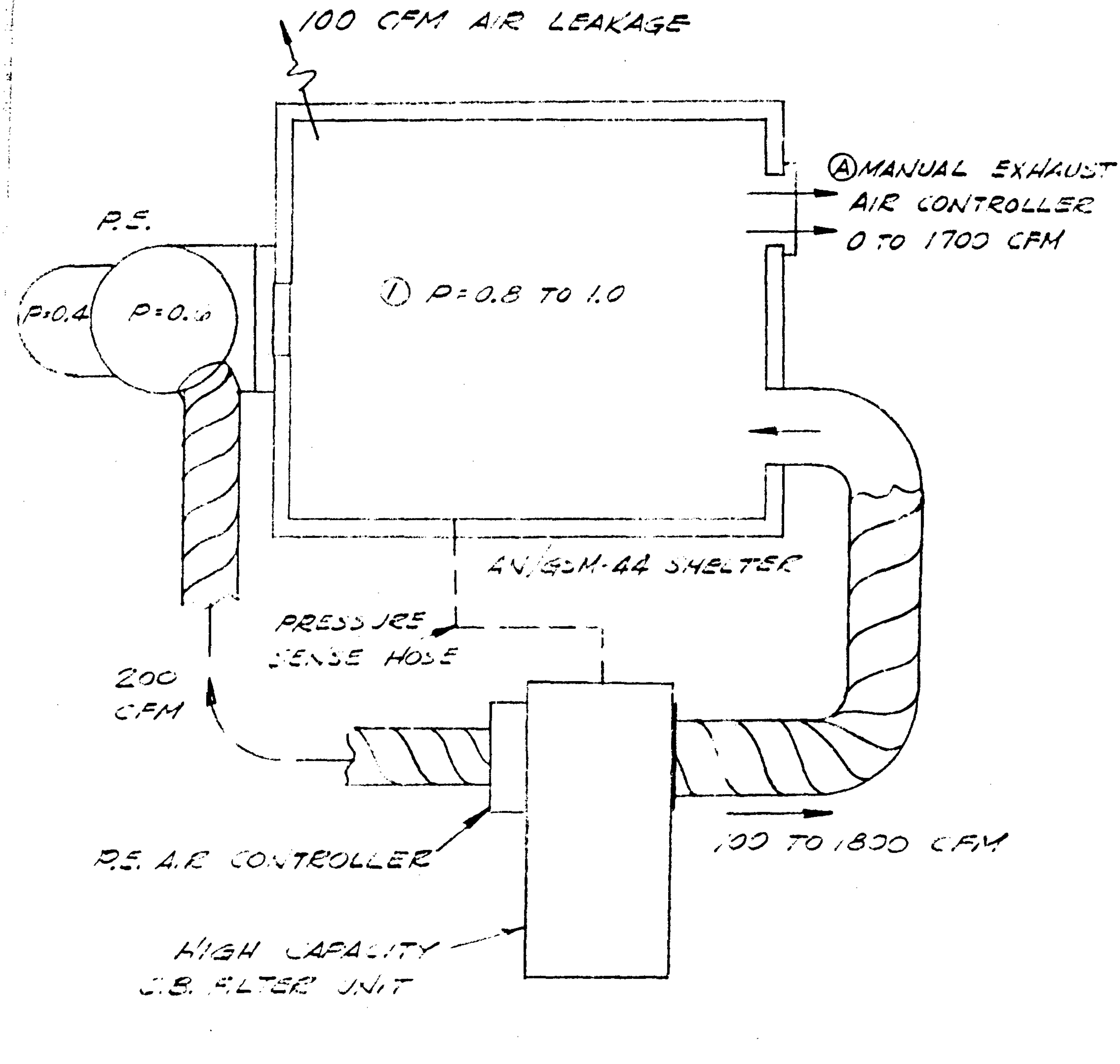
1. Approach D has the lowest power requirements of the approaches described herein for high capacity Filter Units.

DISADVANTAGES

1. Approach D furnishes no control of internal shelter temperature, either in winter or summer ambient temperature extremes. Therefore the range of ambient temperatures through which reasonable internal shelter temperatures can be maintained in the AN/GSM-44 shelter will be from approximately $0^{\circ}F$ to $+85^{\circ}F$ unless additional heating-cooling is provided in the AN/GSM-44 Shelter.

2. Same as disadvantage 2 of Approach C.

APPROACH "D"



① P = PRESSURE (INCHES W.G.)

FIGURE 10.

APPROACH E

400 CFM FILTER UNIT - NO AUXILIARY HEATING-COOLING

Reference: Figure 11.

DESCRIPTION

This approach utilizes the existing 400 CFM HAC Filter Unit 1530300-100. For summertime operation the entire output of the Filter Unit is delivered to the shelter, and approximately 200 cfm of air is drawn from the shelter and routed to the Protective Entrance for scavenging purposes. For winter operation the ducting is changed to bypass the P.E. scavenge air around the shelter and maintain filtered air input to the shelter at a minimum.

EQUIPMENT OPTIONS

None

CONTROL OF SYSTEM

1. The Filter Unit automatic damper will be connected to regulate pressure inside the shelter to prescribed limits.
2. In switching from winter to summer operation and vise versa the duct arrangement will be changed and the system will be rebalanced to establish proper flow rates and pressures.

POWER REQUIREMENTS

1530300-100 Filter Unit - 1.9 KW (208 V, 3ph, 60 cps.)

ADVANTAGES

1. Low power requirements.
2. Equipment can be made quickly available for furnishing interim CPE support to the AN/GSM-44 Shelters.

DISADVANTAGES

1. Extreme internal shelter temperatures will exist in the shelter and Protective Entrance under summer operating conditions. The following is expected:

	100°F Ambient	125°F Ambient
Air Inlet Temp To Shelter °F	111	136
Average Internal Temp. °F (Mean Between Inlet and Outlet)	119	144.3
Discharge Air Temp. (Also Temp of Air to Prot. Entrance) °F	127	152

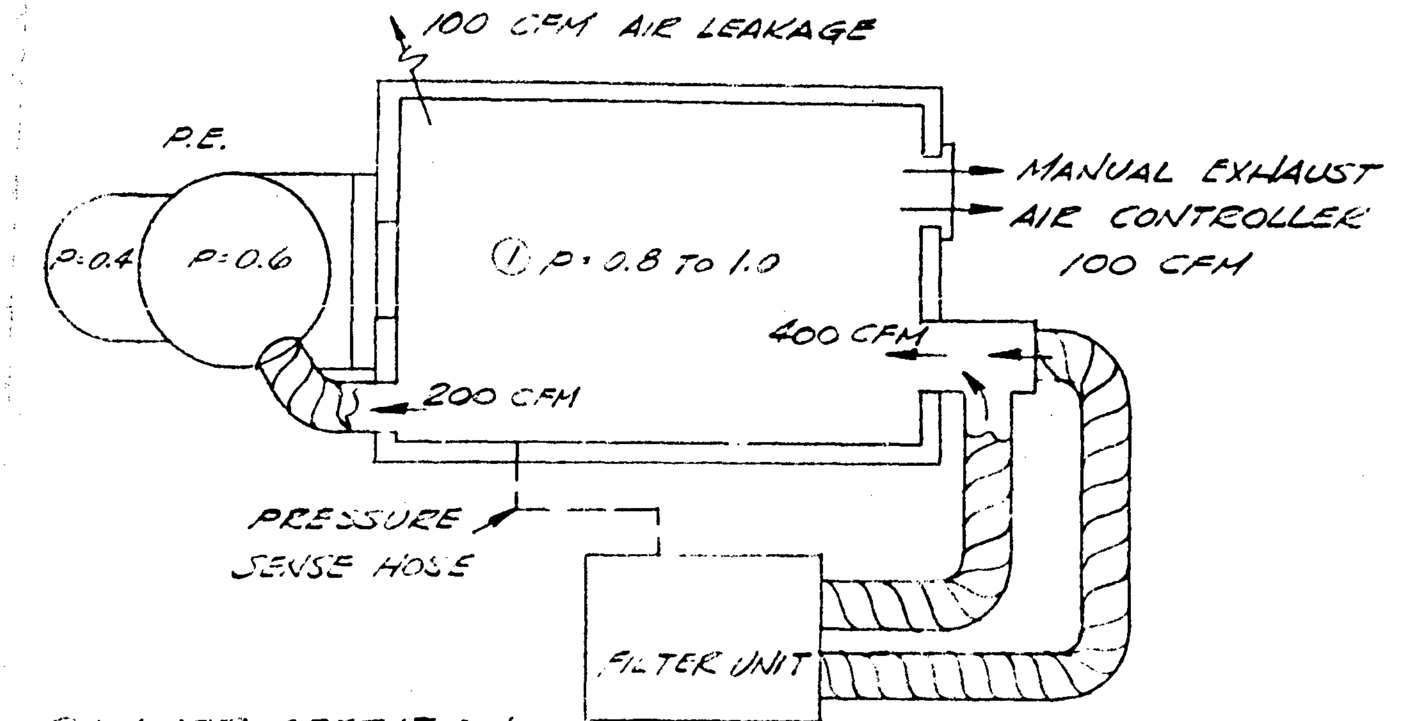
2. Winter operation heating is inadequate. The following temperatures are expected:

Ambient Temp. °F	Internal Temp. °F
0	48
-40	+6
-65	-19

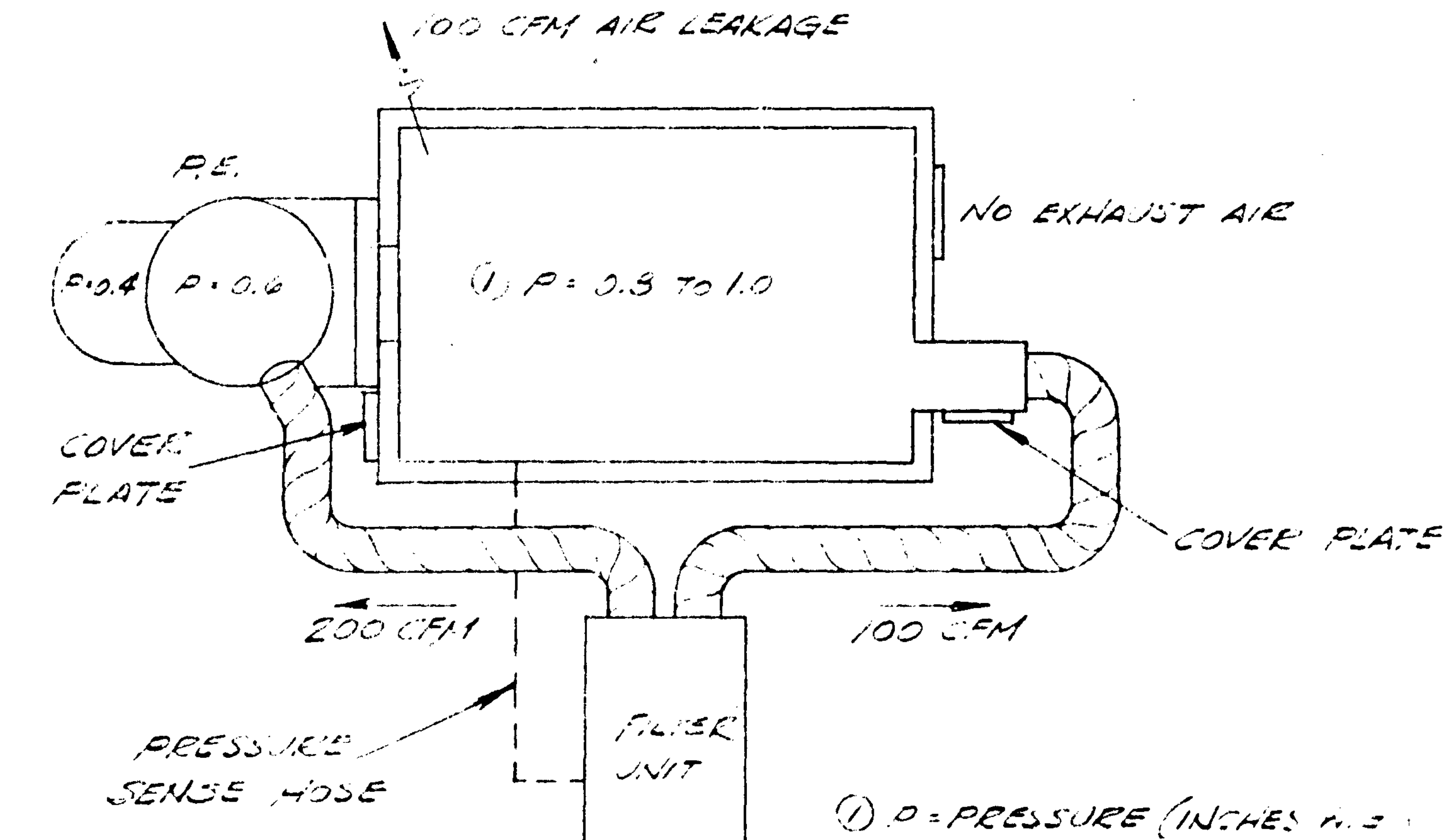
NOTE: As a result of 1 and 2 above, use of this approach is recommended for ambient temperatures from approximately $0^{o}F$ to $75^{o}F$.

3. The AN/GSM-44 System presently requires only single phase power 115 V - 60 cps. Latest information at HAC indicates that generators available for the AN/GSM-44 have 3 phase power capability, but it is not known whether the generators can supply 3 phase power to a Filter Unit and single phase power to the AN/GSM-44 simultaneously. If this is possible, a special power cable would be required to conduct power from the generator - through the shelter junction panel to the control box inside. If the generator cannot be used in this manner, either an additional generator must be provided or a 60 cps single phase CB Filter Unit would be required.

APPROACH "E"



SUMMER OPERATION



WINTER OPERATION

USE OF 400 CFM FILTER UNIT

FIGURE 11

SECTION IV

RECOMMENDATIONS

1. In the interest of providing suitable working environments in all shelters comprising a part of the AN/MSG-4 Anti Aircraft Defense System, Hughes Aircraft Company can recommend only Approach A discussed herein for the AN/GSM-44 System while using Collective Protection Equipment, unless the Government furnishes adequate heating-cooling-power supply equipment to enable usage of the 400 cfm CPE systems recently developed for other AN/MSG-4 System vehicles and shelters.

2. Data presented herein is furnished for Government consideration and action. Hughes Aircraft Company stands ready to furnish engineering consultation on data and approaches contained herein, and recommends that the existing contract be extended to cover additional detailed design study (to establish firm equipment configurations and sizes) and firm proposals on approaches of interest to the Government.

3. With respect to making a recommendation on the exact capacity of a high capacity Filter Unit for use with the AN/GSM-44 System, HAC is reluctant to do so without additional study. It is noted that the average shelter temperature of the AN/GSM-44 is reduced only 2°F by increasing ventilation rate

from 1000 CFM to 1800 CFM. (In the AN/MRC-69 System the corresponding temperature reduction is approximately 3.5°F.). On the other hand, the increase in ventilation rate would increase equipment sizes, weights, and blower power requirements in nearly direct proportion. The fact still remains that internal temperature conditions with a high capacity filter unit are too high.

4. Inasmuch as the AN/GSM-44, AN/GSS-1, AN/GSS-7, AN/MRC-69, and AN/MRC-73 Systems all have this same common problem, it is recommended that consideration for the final approach be directed toward solving this major problem for all systems referenced, and those yet to come.